Mu2e-doc-1937-v2

The Background Cocktail

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Mu2e Weekly Meeting

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Comment

- This talk will discuss overlaying backgrounds on top of events that contain a single conversion electron.
- The specific example is building events to be used for studies of pattern recognition in the TTracker.
  - Ensure that everything is counted exactly once.
- The techniques and tools can be used to study the other detector sub-systems.

The Problem

- Per proton pulse (Mu2e-doc-1774, Mu2e-doc-1865)
  - 35,988 DIO
  - 5,560 ejected protons
  - 10,850,000 beam electrons
  - Plus many more,
- How do we simulate all of this in time with a single conversion electron?
  - CPU time required is huge, many, many hours per event.
  - Memory limits: we want to retain the full history of all particles between the generated particle and the hit making particles.
- The key to the answer:
  - Only a tiny fraction of background particles create any hits.

The Solution

- Generate large samples of each background process
  - One generated particle per event.
  - With one exception, usually use the full phase space:
    - t > 500 ns
    - Hits from earlier particles clear the detector before live gate.
  - Send these events through G4.
  - Write out only events with a least one StepPointMC in the detector(s) of interest.
- When simulating signal events
  - Read in or generate+g4 one conversion electron
  - Overlay appropriate number of events from each of many independent background streams.
  - Make StrawHits (digis) after overlay.

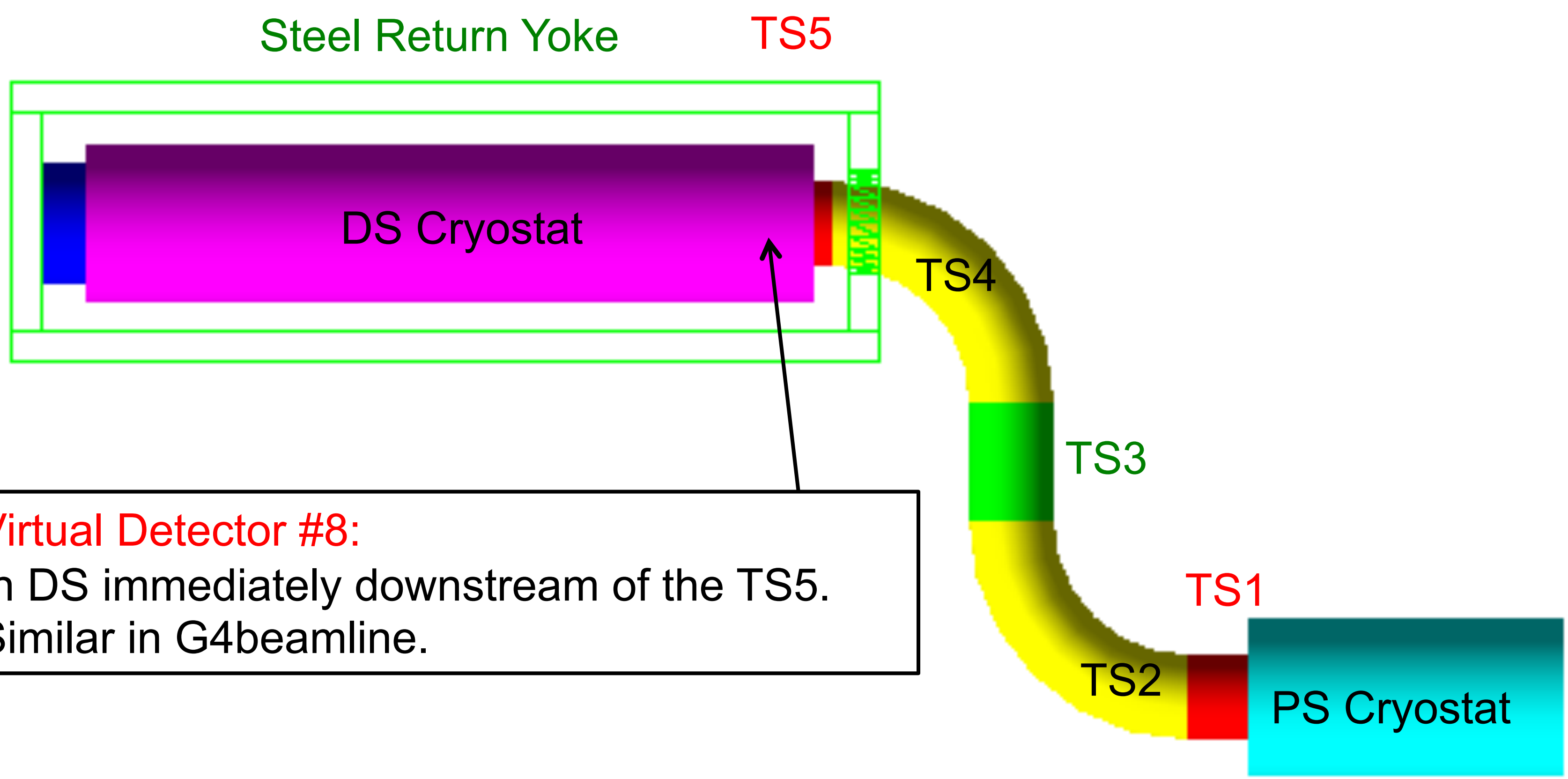
Some Language

- StepPointMC
  - Produced by Geant4.
  - Describes one step of a particle going through a sensitive volume, such as the straw gas.
  - A particle may go through a straw in one step or many steps.
  - Stores a subset of the information from a G4Step object.
- StrawHit
  - Produced outside of Geant4 by a separate module.
  - Data-like. When we read in real data, unpack it and apply first order calibrations, it will look like this.
  - One StrawHit may have a single StepPointMC as a precursor or it may have many as precursors.
  - Code that makes StrawHits records links back to StepPointMCs (in a separate data product).

Some Language

- GenParticle
  - Produced by an event generator.
  - Knows which generator created it.
- SimParticle
  - Produced by Geant4
  - One for each particle input from generator plus one for each particle created inside Geant4.
  - Has full mother/daughter history.
  - Knows physics processes at birth and death.
- Ejected Proton, Ejected Neutron, Ejected Neutron
  - Particles created by muonic nuclear capture
  - I don’t know of any data for the joint distributions.
  - So these are separate generators.

G4 Geometry Plan View



Virtual Detector #8:
In DS immediately downstream of the TS5.
Similar in G4beamline.

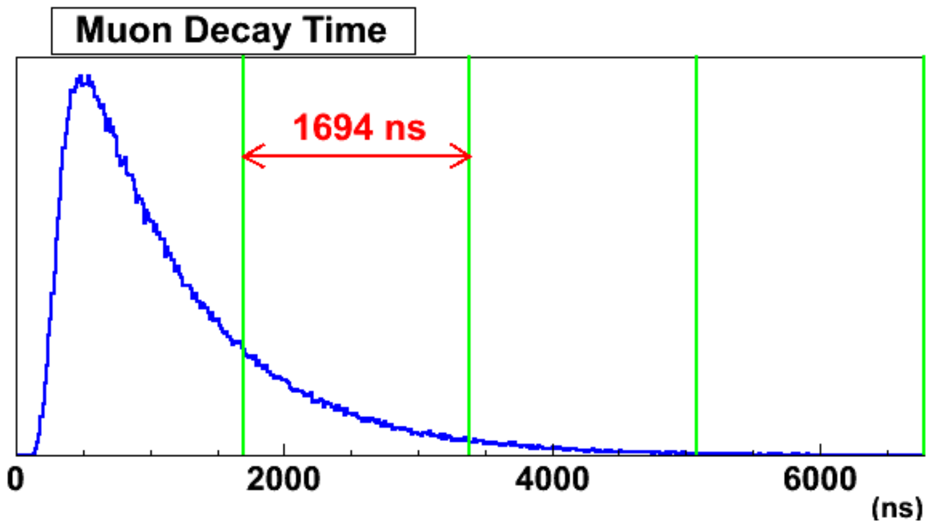
What's in the Geometry

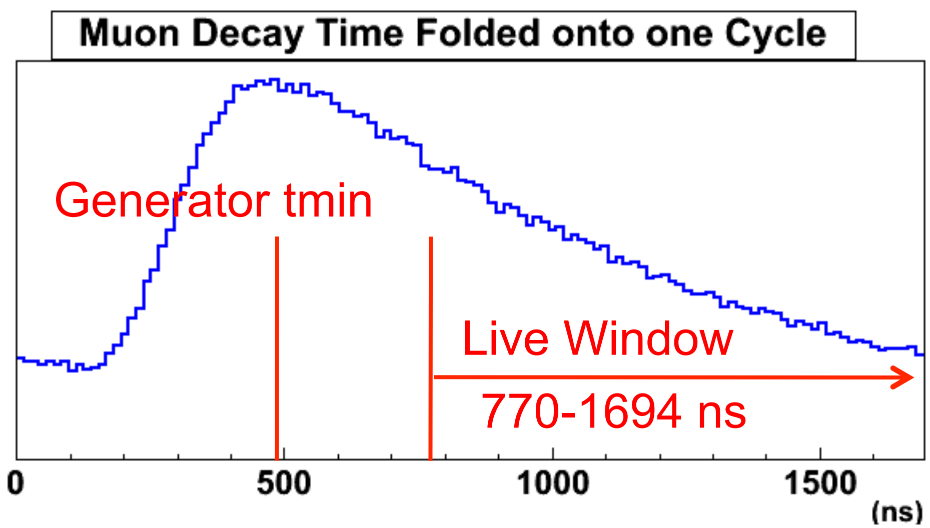
- Muon beamline, including collimators
- Production target
- Stopping targets
- Proton absorber
- Neutron absorbers
- TTracker
- Calorimeter crystals and APDs
- Muon beam dump.
- Cryostats
- Cosmic ray veto scintillators.
- Residual gas in DS:
  - 10^{-4} torr of StrawGas.
- Return yoke.
- Support rings for the TTracker.
- No other support materials.

Sources of Background

- From stopped muons:
  - DIO
  - Muon nuclear capture: protons, neutrons, photons.
  - Treated as 4 independent processes.
- Beam particles, excluding muons that stop.
- Not studied in this talk; can be added later
  - Most neutrons produced from the PS/TS
    - Most miss virtual detector 8 when entering DS.
  - Muonic X-ray cascade.
- BG from cosmic rays are not important for this study.
  - They make very few hits.
  - Cosmic rays producing a real 105 MeV electron is a separate study.

Processes From Stopped Muons



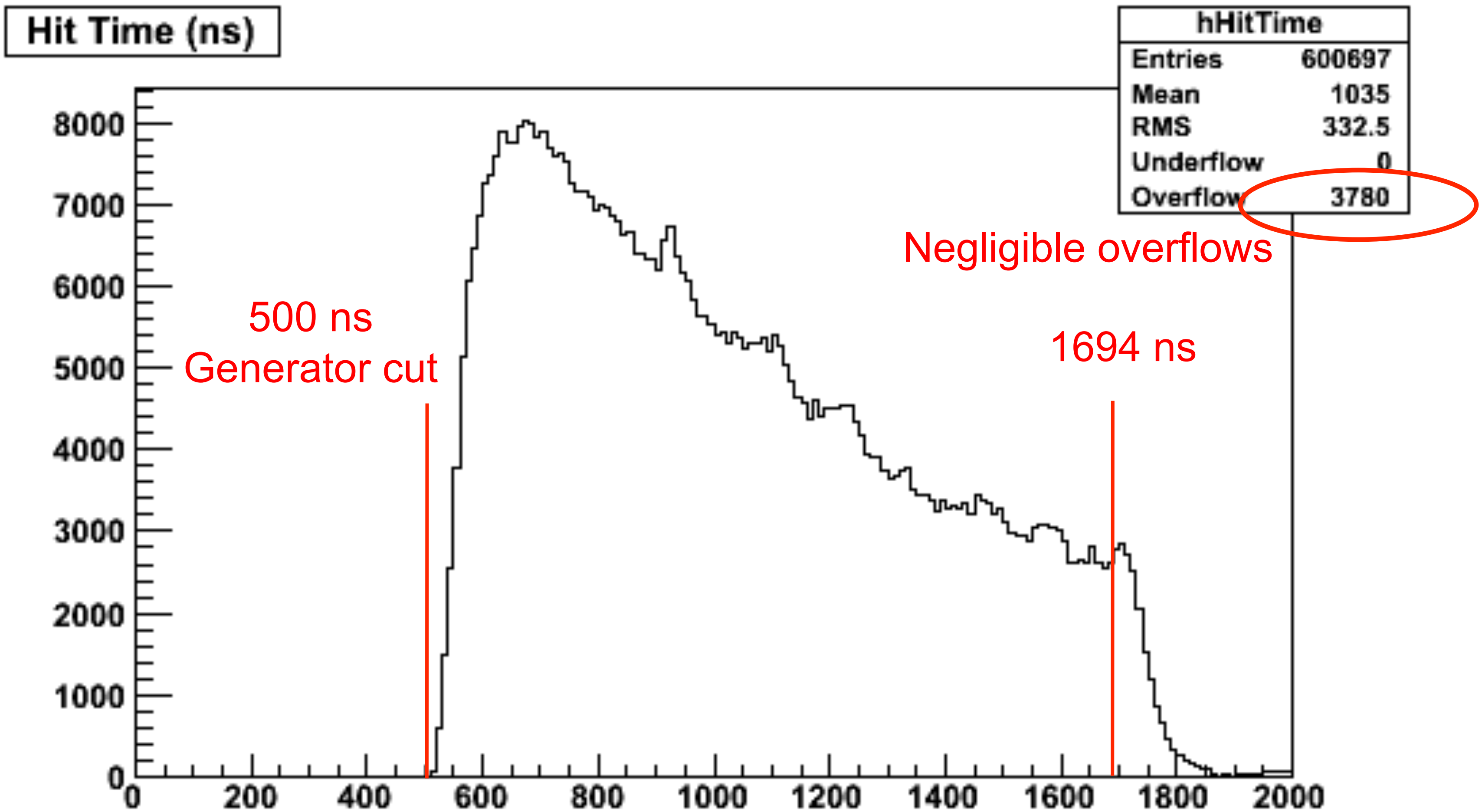


- Full computation of muon stopping time and position.
  - G4 in art or G4beamline.
  - Inc. proton time shape.
- Convolute with exponential decay.
- Fold into one cycle of the muon beamline.
- Minimum time cut safely before start of live window.

DIO Example

- My grid jobs:
  - Single track events generated: 250,000,000
  - Events with >0 hits in tracker: 129,060
  - 0.000516 events with tracker hits per DIO
- From Gianni:
  - 35,988 DIO per proton pulse (Mu2e-doc 1774-v2)
  - 22,456 with t>500 ns (62.4%)
- 22,456 × 0.000516 = 11.6
  - Draw 11.6 events per conversion electron from my DIO background files.

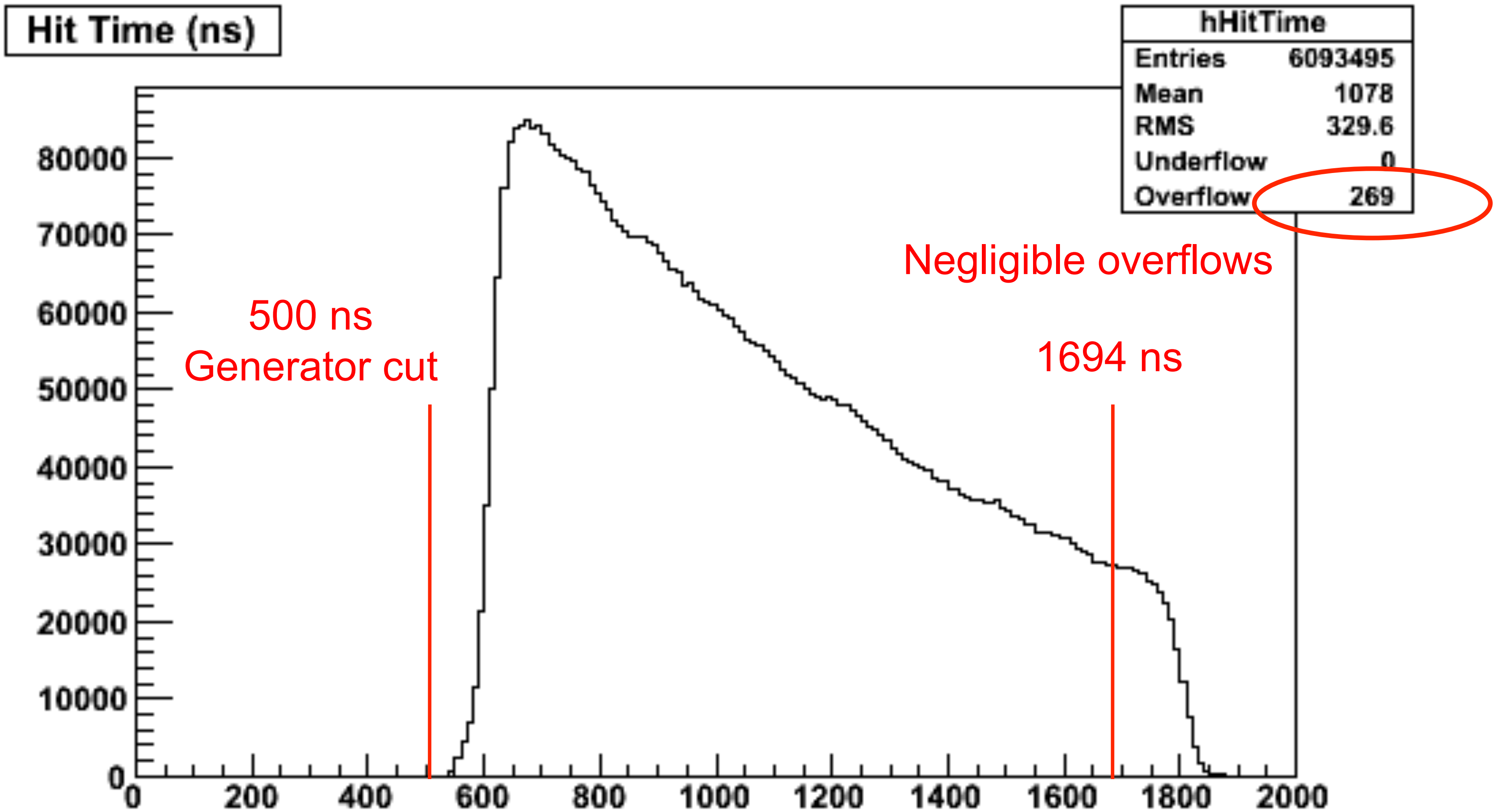
StrawHits From DIO



Ejected Protons

- My grid jobs:
  - Single track events generated: 70,000,000
  - Events with >0 hits in tracker: 297,063
  - 0.00424 events with hits in tracker per ejected proton
- From Gianni: Mu2e-doc 1774-v2
  - 5,560 ejected protons per proton pulse
  - 3,513 with t>500 ns (62.4%)
- 5,560 × 0.00424 = 14.9
  - Draw 14.9 ejected protons per conversion electron from my ejected proton background files.

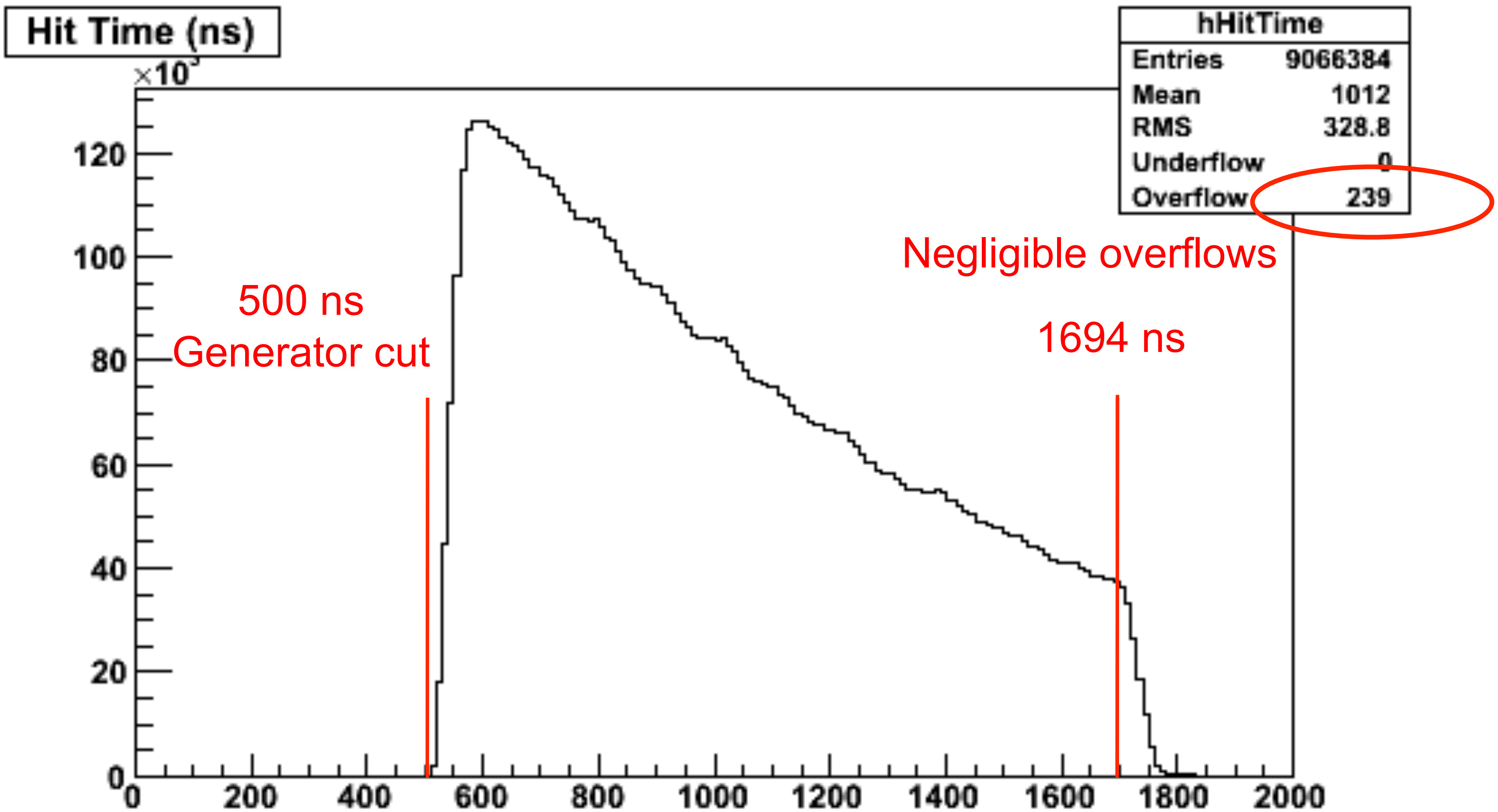
StrawHits from Ejected Protons



Ejected Photons

- My grid jobs
  - Single track events generated: 1,000,000,000
  - Events with >0 hits in tracker: 764,782
  - 0.000765 events with hits in tracker per ejected proton
- From Gianni: Mu2e-doc 1774-v2
  - 112,500 ejected photons per proton pulse
  - 70,200 with t>500 ns (62.4%)
- 70,200 x 0.000765 = 53.7
  - Draw 53.7 ejected photons per conversion electron from my ejected photon background files.

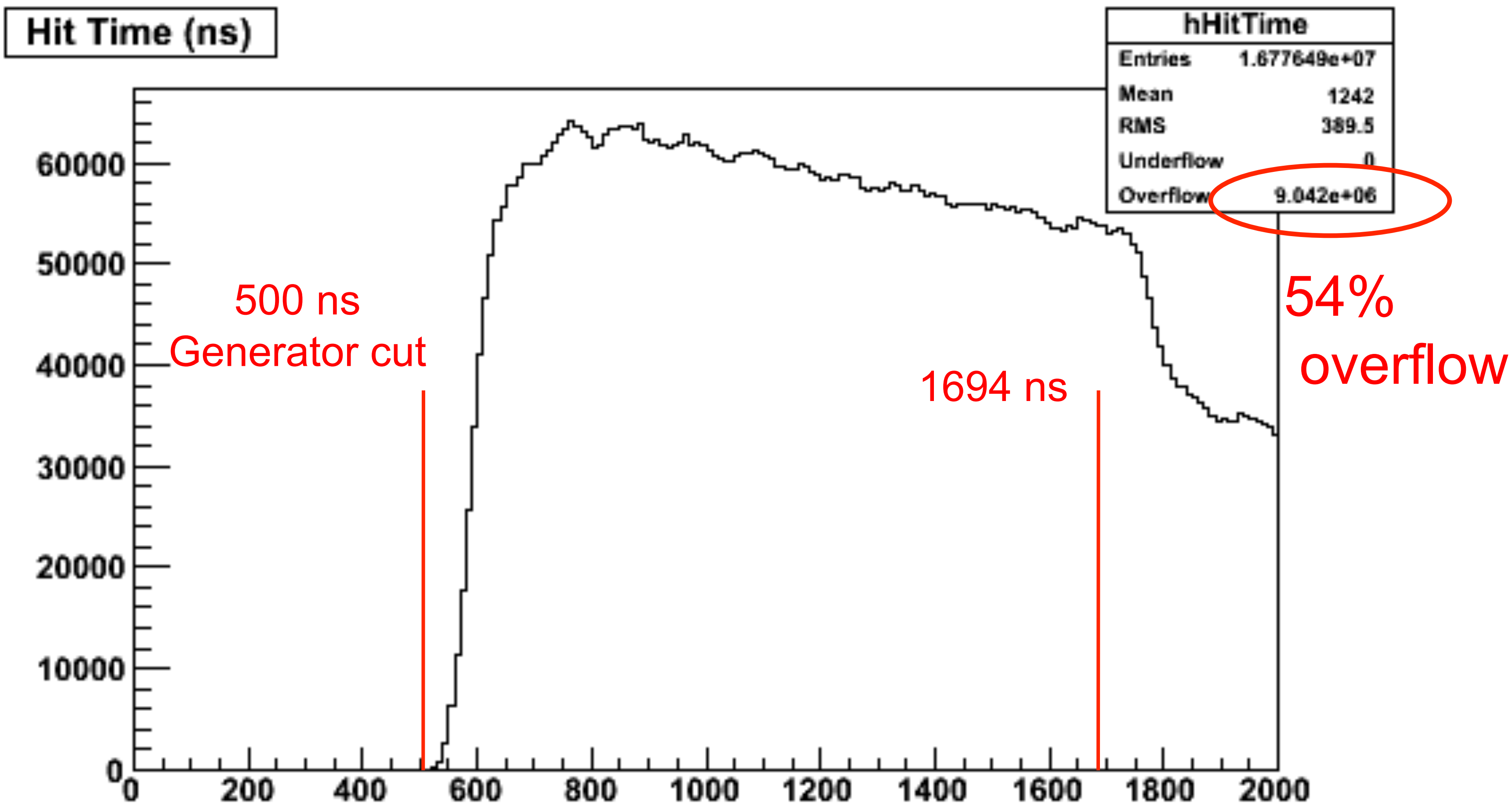
StrawHits from Ejected Photons



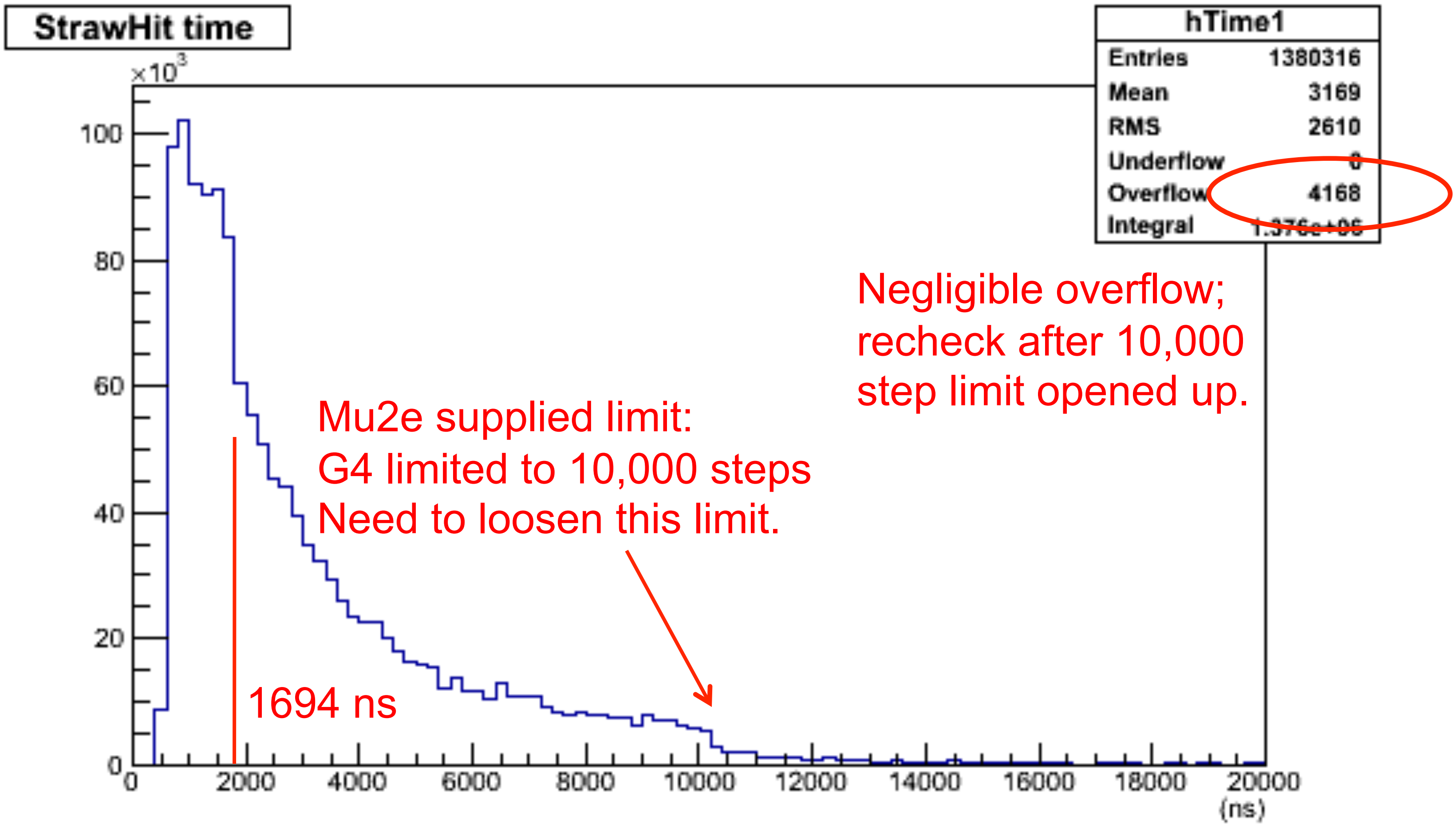
Ejected Neutrons

- My grid jobs
  - Single track events generated: 1,000,000,000
  - Events with >0 hits in tracker: 1,216,181
  - 0.00122 events with hits in tracker per ejected neutron
- From Gianni: Mu2e-doc 1774-v2
  - 84,434 ejected neutrons per proton pulse
  - 52,686 with t>500 ns (62.4%)
- 52,686 x 0.00122 = 64.3
  - Draw 64.1 ejected neutrons per conversion electron from my ejected neutron background files.

StrawHits from Ejected Neutrons



StrawHits from Ejected Neutrons



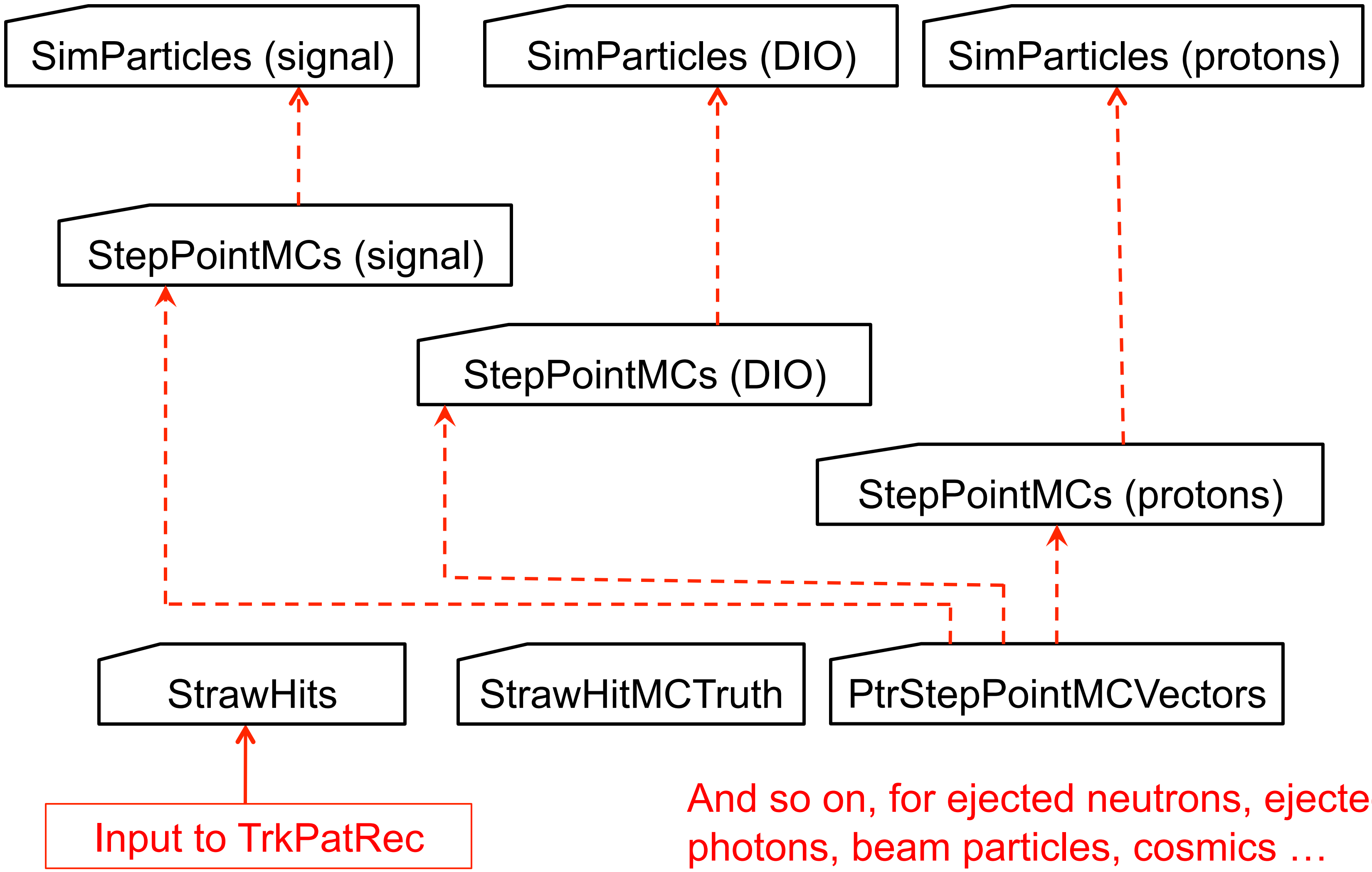
To Fix Ejected Neutrons

- Rerun generation (a day on the grid).
- Start generation from t=0
- Loosen the limit of 10,000 G4 steps
- Fold hits at long times into the first cycle of the muon beamline.
  - Do this at the StepPointMC level, during mixing input; shift the entire event record to an earlier start time.
- Do I need to change the normalization?

Plan for Beam Particles

- Start with beam particles entering the DS
  - From either G4 in art or G4beamline
- Shoot single particle events.
- Tell G4 to ignore the decay products of muons that are captured in the stopping targets.
- Otherwise process through G4 normally.
- Only write out events with at least one StepPointMC in the detector(s) of interest.

Event Mixing



And so on, for ejected neutrons, ejected photons, beam particles, cosmics …

Non Uniform Proton Bunch Intensity

- Except for neutrons, this is easy.
- Need a model for the distribution of bunch intensity.
  - Express it as a multiplier on the nominal intensity.
  - First guess: flat from 0.5 to 1.5?
- At start of each event, draw a random variate from this distribution.
- In each mixing module,
  - Multiply the mean of the Poisson distribution by this multiplier.
  - Draw Poisson variate from a distribution with the scaled mean.
- Neutrons:
  - Need to deal with folding the StepPointMC time distributions. Working on this now.

Making StrawHits (1)

- Input:
  - Many StepPointMCCollections
- If many StepPointMCs are on one straw, close in time, they form a single hit.
  - For each step compute arrival time at two ends of straw.
  - Includes drift time, propagation along the wire.
  - Earliest time at reference end sets the TDC; this could be from a delta ray!
  - Compute delta(t) for time division with earliest time at other end.
- Allows multiple hits on one straw if there is 100 ns gap in the pulses on that wire.
- Compute energy deposition in the straw but not a digitized waveform.

Making StrawHits (2)

- Bookkeeping is complete but physics details remain primitive:
  - Constant drift velocity
  - Constant position resolution as a function of drift distance.
  - Perfect charge collection (variations in ionization per unit length is included in G4).
  - Perfect electronics response.
  - No model of cross-talk electronic cross-talk.
- Being addressed by Xiaobo Huang (U. Houston).

Making CaloHits

- Record StepPointMCs:
  - For each step in a crystal volume.
  - For each step in a readout volume (APD).
  - A direct hit on a readout volume is presumed to saturate it.
- CaloHit
  - Represents what we would see in a real experiment: a pulse height and time on a readout channel.
  - Status similar to StrawHits:
    - Bookkeeping is complete, including multiple hits on one readout within on pulse of the muon beamline.
    - Physics remains very primitive: perfect light collection …
- CaloCrystalHit
  - A hit crystal object formed from 1 or 2 CaloHit objects

Making CRV Hits

- The StepPointMCs are recorded in the scintillator planks but the next steps are not done.

What are we Missing?

- Most neutrons produced in the PS and TS
  - From production target, heat and radiation shield, collimators.
  - They will enter DS in a way that misses virtual detector 8.
- Can significant non-neutrons also enter the DS in a way that misses virtual detector 8?
- Still need to do big MC run for beam backgrounds.
- Finish code to deal with non-uniform bunch sizes.
- Real energy spectrum for ejected photons.
  - Uses MECO model: flat 0 to 7 MeV.
- Support materials that can produce albedo.

One Last Comment

- We can use these tools to make
  - Pure background samples
  - Samples of pure background plus one event from the high momentum tail of the DIO spectrum.

Summary and Conclusions

- We have factorized the backgrounds into separately computable independent pieces.
- Have not missed anything or double counted.
- Still need high statistics runs for some sources.
- Event mixing used to merge many background streams on top of signal events.
- Can mix 10,000 signal events in ~ 1 hour real time.
- Status of pattern recognition with these backgrounds will be reported next week

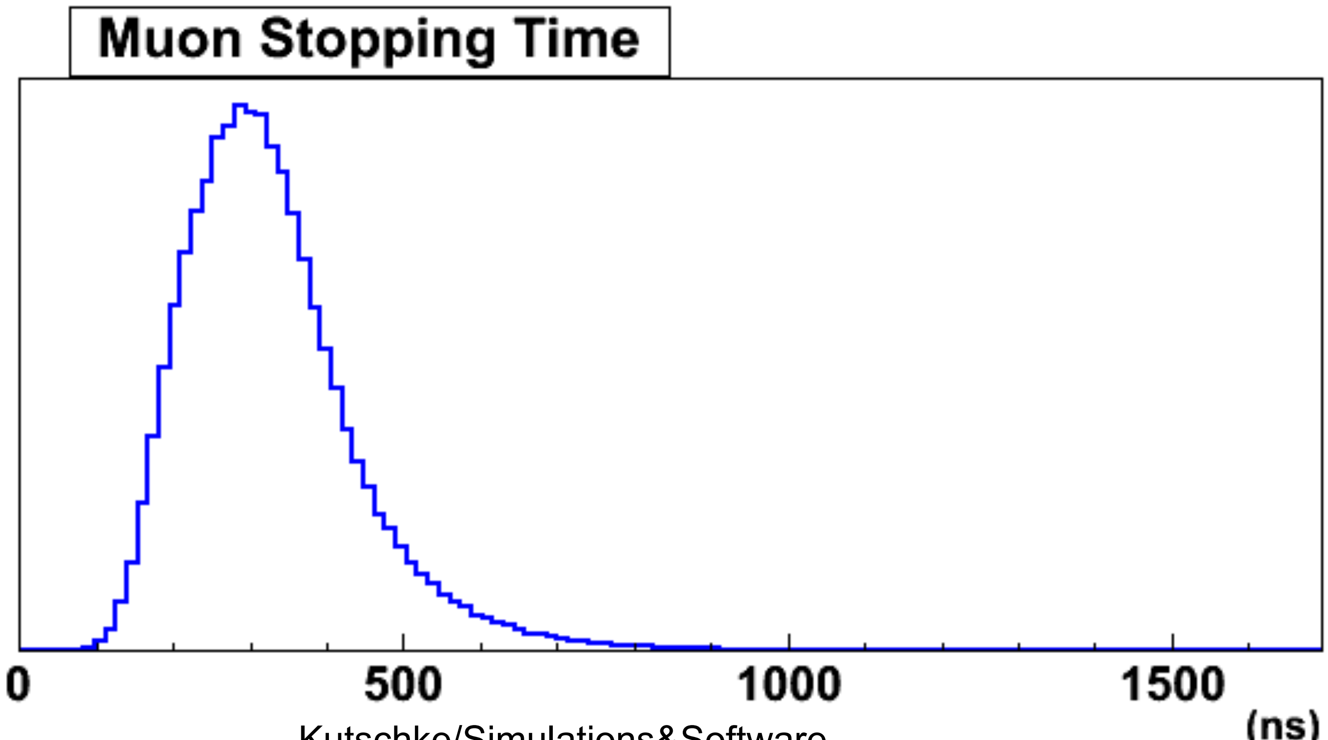
Backup Slides

Comment

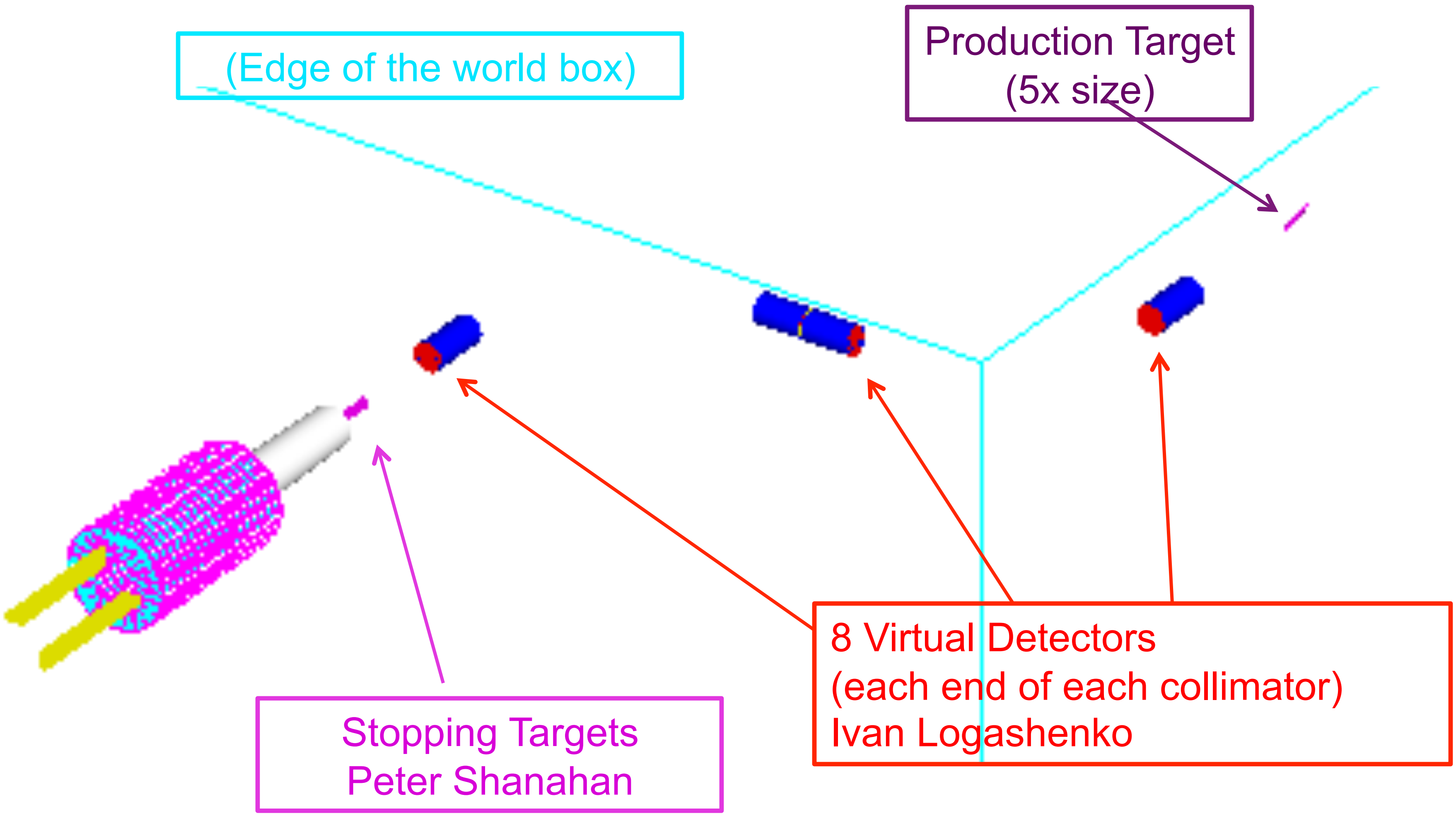
- Do the beam backgrounds first.
- Use the stopped muons to seed the (position,time) file used to generate processes that come from stopped muons.
- I think it's clear that, this way, there is no multiple counting.
- To date I have done separate runs to make the stopped muon (position,time) file.
  - There is no multiple counting in the ensemble of events but a single muon may have different fates in the two runs!

Steps 1 and 2

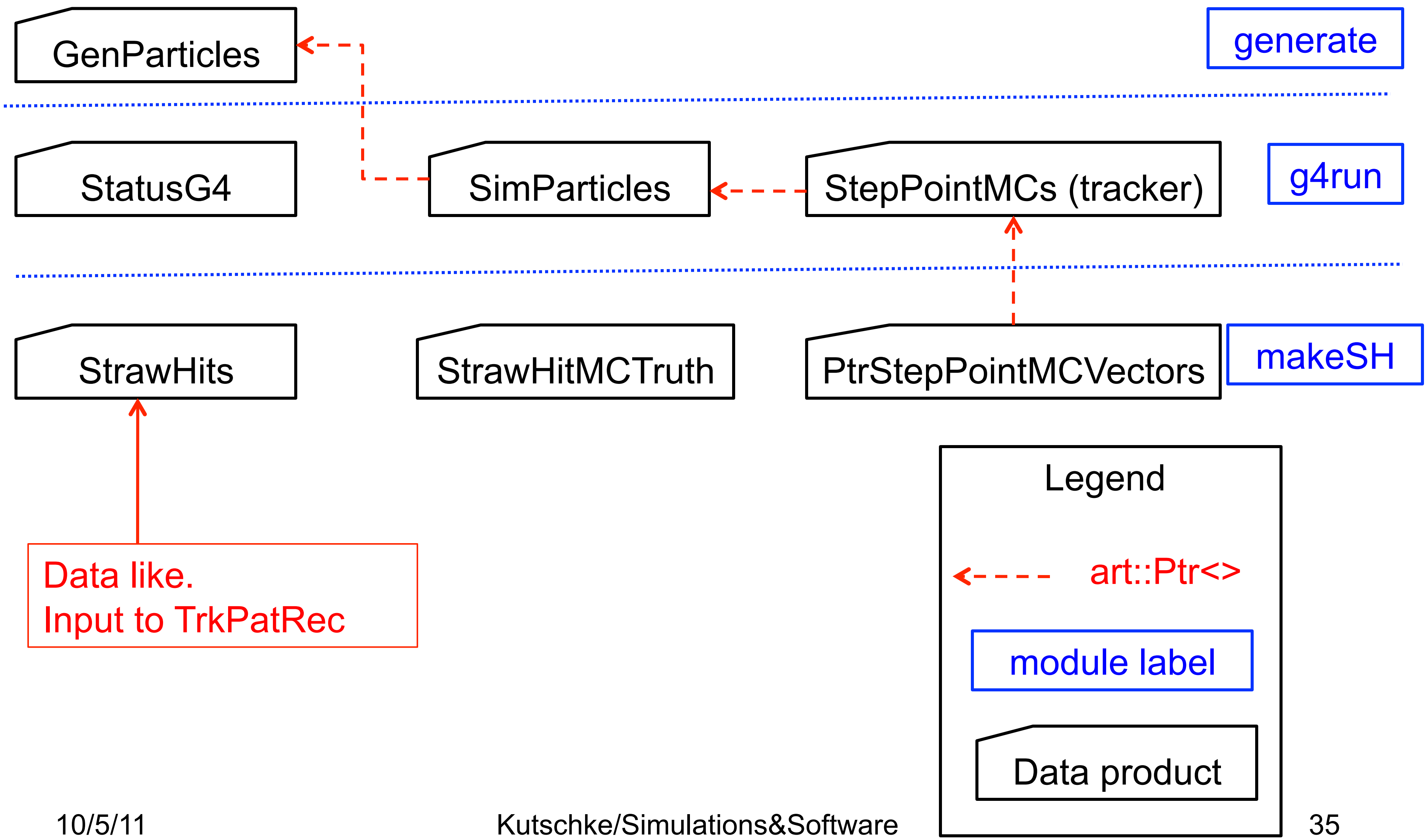
- Step 1: protons on production target
  - Save muons entering DS
- Step 2: output of step 1.
  - Save time and position of muons stopping in foils



View From (45º,45º)



Data Products Related to StrawHits



Event Mixing

DIO Background File

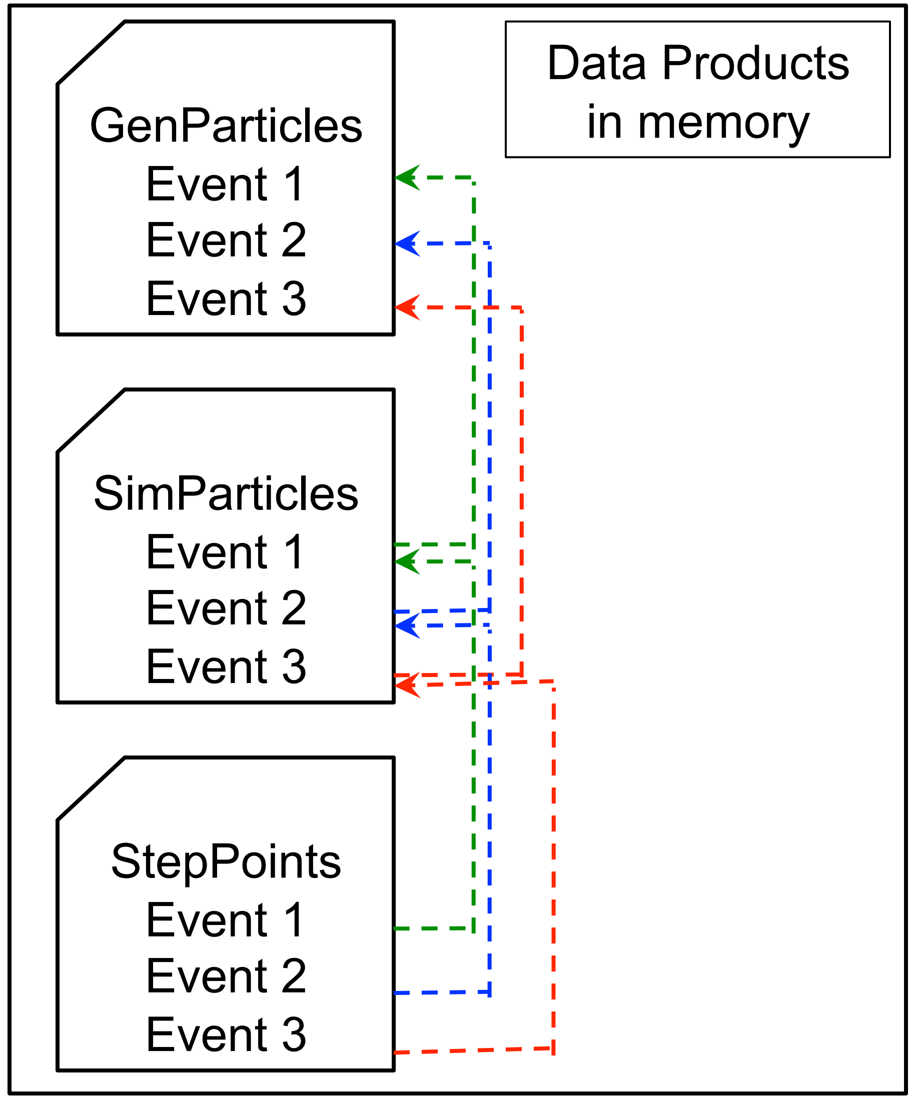
	Gens	Sims	Steps	StatusG4
Event 1				
Event 2				
Event 3				
Event 4				

For each signal event, choose N events from the DIO background file, mix the N GenParticleCollections in the file into 1 in memory.

And so on for other data products.

Renumbers items for events 2, 3 …

Therefore: reseat all art::Ptr objects.



Example: StepPointMCs

DIO Background File

	Gens	Sims	Steps	StatusG4
Event 1			3	
Event 2			2	
Event 3			4	

Size of StepPointMCCollection

StepPointMCCollection in Memory

StepPointMCs
0 – (1,0)
1 – (1,1)
2 – (1,2)
3 – (2,0)
4 – (2,1)
5 – (3,0)
6 – (3,1)
7 – (3,2)
8 – (3,3)

(n,m) =
(event # in bg file, index into the collection)